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Virtual Player of Melodic Abstraction Instruments for Automatic *Gamelan* Orchestra

Khafiizh Hastuti, A. Zainul Fanani, Arry Maulana Syarif
Faculty of Computer Science
Dian Nuswantoro University
Semarang, Indonesia
afis@dsn.dinus.ac.id, zafanani@yahoo.com, arrymaulana@gmail.com

***Abstract*—This research aims to bring a *gamelan* orchestra, which is a Javanese cultural heritage, to the hands of the user by using mobile technology. The virtual player in this system is designed to lead users in playing or learning *gamelan* instruments. The various skill level of user is hardly considered to be accommodated. A system which is able to read notation sequences automatically is needed to develop a virtual player in this research. This allows the system playing every inputted *gamelan* song notations with various tempos. Type of *gamelan* song notations structure explored in this research is melodic abstraction notations called *balungan*. The melodic abstraction notations of *gamelan* song are recorded into array data for the system reading them and giving outputs of sound, visualization, and animation of the melodic abstraction instruments. The user acceptance test which involves *gamelan* music experts is conducted to measure the accuracy of the system's ability in playing the instruments, such as reading the notations, synchronizing the sound and animation, and tempo of the play. The accuracy is evaluated based on features of orchestra and a single instrument. The result shows that the accuracy for orchestra feature reaches to 71.1%, and for a single instrument feature, the accuracy reaches to 84.4%. Another evaluation is to measure the clarity which represents the system's ability in visualizing the animation, sound, navigation, learning, interactivity. The result of clarity evaluation is 78.1%.**

Keywords—gamelan; virtual music player; automatic notations reading

I. INTRODUCTION

This research aims to give a contribution of preservation of Javanese cultural heritage called *gamelan* music using computer technology. *Gamelan* is a traditional music ensemble from the land of Java. A modern *gamelan* orchestra can have 80 instruments, 25 players, and some singers [1]. As a music orchestra, *gamelan* has obstacles that are typically faced by others kind of music orchestras. Music orchestra is something big that need expensive cost, a large room, expert players, and one may takes many years or even decade to mastering instruments of the orchestra [2].

Gamelan instruments are something rare to play for young people nowadays. A research conducted by [3] resulted data that 66.7% of senior high school students in Indonesia are never learn *gamelan* music, and 76.7% of them cannot play *gamelan* instruments. *Gamelan* preservation strategy is a problem to solve.

The use of computer technology can be an alternative strategy to solve the problem mentioned above. *Smule* is an example of the use of computer technology for music that succeed in bringing the music instruments into computer application. Reference [4] mention that the *Smule Ocarina* is one of the applications that represents a wind instrument which is fully leveraging its wide array technologies, such as microphone input, multitouch, accelerometer, real-time sound synthesis, and high performance graphic. Various approaches are used in exploring the interaction in music application. Reference [5] proposed the use of the magnetic field sensor embedded in mobile devices to serve musical performance that lets the user utilize the surrounding 3D space to bring a wide-spectrum of unique. A gestural interface which involves hand movement, virtual object processing, and parameterized sound synthesis is used by [6] to reduce the motor and cognitive load for the sound designer. A virtual instrument system has been designed using an optical multi-touch tabletop serves as the input device for multiple users and an algorithmic pipeline interprets user's interactions [7]. The system presents a xylophone and a set of drums of various sizes and shapes, and support up to six users in interacting with it simultaneously.

As the other music applications built using a computer technology and mobile technology to make an access for the instruments easier, the use of these technologies are also need for *gamelan* music. There are applications containing *gamelan* instruments that have been released in the mobile application markets, such as *app store* and *play store*. The *gamelan* instrument applications still have limited features, especially learning feature, playing orchestra feature, database of notations of gamelan song.

The basic idea of the development of a virtual *gamelan* orchestra player is bringing the orchestra to the hands of the user instead of waiting for them taking steps to reach the instruments. In this research, a system is designed to support an interaction with user in playing *gamelan* orchestra using computer technology, such as giving lessons for mastering

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gamelan instruments, helping user in playing gamelan songs, supporting unlimited database of notations of gamelan songs. The system designed in this research called virtual *gamelan* orchestra player, is not only presents virtual instruments, moreover it can represent a *gamelan* player which can play the *gamelan* instruments. The skill of user in handling a mobile device, including learning the interactivity instruments and songs in the virtual *gamelan* orchestra player, is hardly considered to be accommodated. The virtual *gamelan* orchestra player should be able to set its play at various level skill of user.

The mobile technology is considered as the platform for running the virtual *gamelan* orchestra player application. This technology growth rapidly, and now it reaches to 44 billion applications downloaded around the world in 2016 [8]. This makes mobile application become suitable and easier as a platform in delivering the virtual *gamelan* orchestra player to the users.

Developing a *gamelan orchestra* in a mobile application needs a smart system which can use *gamelan* instruments to play *gamelan* songs automatically. In order to serve for unlimited *gamelan* songs and various tempos of play, the virtual *gamelan* orchestra player developed in this research is designed to be able to read the gamelan song's notations automatically, or able to read a gamelan sheet music.

II. *GAMELAN* MUSIC

A. Gamelan Instruments

Gamelan instruments are mostly made of bronze that is a mix of cooper and tin with ratio 3:10 [9]. These instruments include of *gong, gender, bonang barung, bonang penerus, demung, saron barung, peking, kenong, kethuk, slenthem*. Other types of instruments in *gamelan* are a wooden xylophone called *gambang*, a set of two headed drums called *kendang*, two-stringed bowed instrument called *rebab*, a plucked zither-type instrument called *celempung* or *siter*, and a bamboo flute caled *suling* [10]. Fig. 1 shows some of *gamelan* instruments.

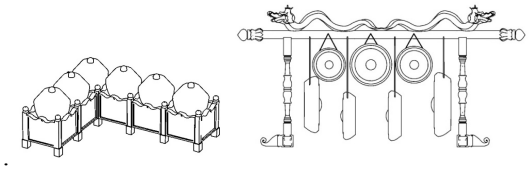

Fig. 1. Some of *gamelan* instruments: *kenong* (left), *kempul* (right)

B. Tuning and Tuning Adjustment Systems

Gamelan are divided into two tuning systems called *laras*, which are *laras slendro* and *laras pelog*. *Laras slendro* consists of 5 tones that are 1, 2, 3, 5, 6. *Laras pelog* consists of 7 tones that are 1, 2, 3, 4, 5, 6, 7. A complete *gamelan* set is actually a double set, that is a *slendro gamelan* and a *pelog gamelan*, although they are never played simultaneously [10]. Each *laras* has tuning adjustment systems called *pathet*. *Laras slendro* consists of *pathet nem, pathet sanga* and *pathet manyura*. *Laras pelog* consists of *pathet lima, pathet nem* and *pathet barang*.

C. Function of Gamelan Instruments

Gamelan instruments have their function in the ensemble classified into time, melody and structure [11]. *Kendang*, a two headed asymmetrical drum, is the instrument which organizes the time in the playing with a concept concerning the interaction of tempo (fast, medium, slow). The musical structure in *gamelan* composition is controlled by type of gong instruments; e.g. *gong, kenong, kempul,* and *kethuk*. The function of melody is divided into three categories, the first is elaborate melodies played by *rebab, gender, gambang,* and *celempung*, the second is melodic abstraction played by *slenthem, demung, saron, peking*, and the third is melodic mediators which offer guidance to the instrument in groups of elaborate melodies and melodic abstraction. This research is limited in developing virtual player of melodic abstraction instruments; therefore the following discussion is focused on this scope.

D. Melodic Abstraction Instruments

There is a melodic line considered as a melodic skeleton called *balungan* [10]. *Balungan* is the abstraction of the melody of *gamelan* song (*gending*). Basically, there are two kinds of balungan, which are *balungan mlaku* and *balungan nibani*. The others variants of *balungan* melody are *balungan gantung, balungan rangkep, balungan ngrancak,* etc. *Slenthem, demung, saron*, and *peking* are the instruments for playing balungan [10][11]. Fig. 2 shows the illustration of *balungan* as an abstraction of a melody which its notations are displayed inside bounding boxes. Fig. 3 shows examples of notations arrangement for *balungan mlaku* and *balungan nibani*.

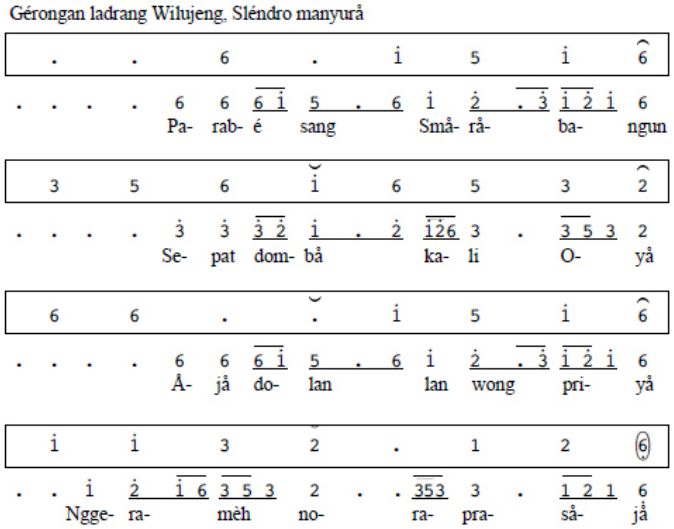

Fig. 2. Examples of *balungan* as melodic abstraction (sumarsam)

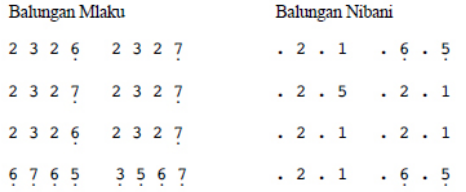

Fig. 3. Examples of *balungan mlaku* and *balungan nibani* (sumarsam)

III. EXPERIMENT

The virtual players of melodic abstraction instruments developed in this research are limited to players of *slenthem, demung, saron* and *peking,* as melodic abstraction instruments (Fig. 4).

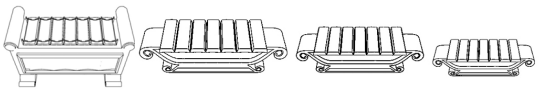

Fig. 4. *Slenthem, demung, saron,* and *peking* (Left to right)

The virtual players of melodic abstraction instruments are designed to be able to read *balungan* notations and automatically give outputs in form of audio, visual and animation based on the inputted *balungan* notations. This makes the system can give a demonstration in playing the instruments, or an interaction play with the user. The model design of the virtual players of melodic abstraction instruments, as seen in Fig. 5, allows user to choose a melodic abstraction instrument, and then choose the actions of play mode which are demonstration or interaction. The demonstration action serves a visualization of technique of the play of the instrument, and the interaction action let the user to interact with the system by playing the instrument whether using *balungan* notations or not. The output is served in term of audio, visual, and animation.

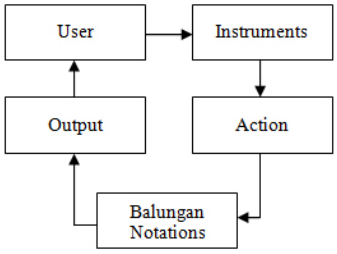

Fig. 5. Model design of virtual players

The development of the virtual players of melodic abstraction instruments for automatic *gamelan* orchestra consists of several phases described below.

A. Dataset Collection

Gamelan song called *gending* is desrcibed as an arrangement of tones which grow into a shape [12]. Gending is classified into *gending ageng, gending tengah* and *gending alit* [11]. The element of *gending* consists of *balungan* and *gatra*. *Gatra* is the smallest unit in *gending* which contains 4 beats or sabetan or notations which usually manifasted as strokes of the balungan instruments [10] [11]. Fig. 6 shows an example of gatra in gending *ladrang laras pelog pathet lima* entitled *Balabak*.

Ladrang Balabak, laras pelog pathet lima

3 2 3 1	3 2 3 5	3 2 3 1	3 2 3 5
. . 5 6	5 4 2 1	3 2 3 1	3 2 3 5

Fig. 6. Example of gatra in a gending

Dataset used in this research are collected based on *laras slendro* and *laras pelog* including each *pathet*, and limited into *balungan* notations of *gending alit*. *Gending* forms which are categorized as *gending alit* and used as dataset are *ketawang, ladrang, lancaran*.

B. Sound Recording

The melodic abstraction instruments in *gamelan* are *slenthem, demung, saron* and *peking*. *Slenthem* provides the lowest octave, *demung* provides the medium octave, *saron* provides the high octave, and *peking* provides the highest octave. Fig. 7 shows the distribution of the register of melodic abstraction instruments for laras slendro and laras pelog.

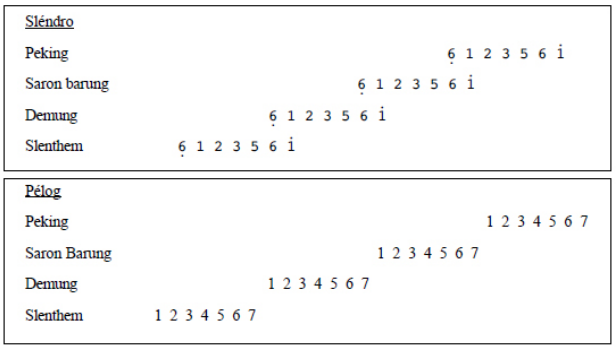

Fig. 7. Distribution of the register of melodic abstraction instruments (sumarsam)

The sound of the melodic abstraction instruments for *laras slendro* and *laras pelog* are recorded based on each keys/instrument blades, and saved into database of instrument sounds.

C. Instruments Visualization

The pictures of the melodic abstraction instruments are taken from the real *gamelan* set photograph. Three of the melodic abstraction instruments, which are *saron, demung,* and *peking* have same shape, but they are different in size. In order to keep the file size of the application, those three instruments are visualized with one picture taken from instrument of *saron*. The scale method is used to display those instruments in the application. The other instrument, which is *slenthem*, is visualized using its photograph. The visualization of the instrument mallets are created separately. The instruments of *demung* and *saron* have same mallet, while instruments of *peking* and *slenthem* have each different mallets. Fig. 8 shows the illustration of visualization of instrument *demung*, which is also used for *saron* and *peking*, and Fig. 9 shows the illustration of visualization of instrument mallets.

Fig. 8. Visualization of instrument of *demung*, *saron*, and *peking*

Fig. 9. Visualization of instrument of *demung* and *saron* mallets (A), *peking* mallet (B), *slenthem* mallet (C)

D. Instruments Animation

The animations of the play of the instrument are display in four steps, which are silent, hit, play, and silent (Fig. 10). The first step is silent, where the instrument mallet is on the stand by position. The second step is hit, where the instrument mallet is on the position of hitting the instrument. The third step is play, where the sound of the key is played, and the instrument mallet is above the instrument, while the blade of the instrument which is struck is visualized with blinking color. The fourth step is the silent, where the instrument mallet is back on the stand by position.

Fig. 10. Animations of the instruments

The distribution of frames for the animation is measured based on the duration of sound of the instrument key. In the document with frame rate 25 fps (frame per second), each of the sound duration takes 8-10 frames, including the echoes. The four steps visualization mentioned above is distributed into 5 frames, with step silent uses frame 1, step hit uses frame 2, step play uses frame 3-4, and back to step silent uses frame 5. This design let the system plays frame 1-5, and calls the sound of the key as well when user hit the instrument blade.

E. Automatic Play Based On Inputted Notations

The system is designed to be able to read and play *balungan* notations automatically. This makes user can adjust tempo of the play in the system. The notation recognition approach is used to design the automatic play feature in the system. First, the *balungan* notations of a *gending* are recorded as array data, and if there is a dot notation in *balungan* notations, then it is converted to 0. Fig. 11 shows the illustration of recording *balungan* notations for *gending* entitled *Suwe Ora Jamu* into array data, and converting the dot notations into 0.

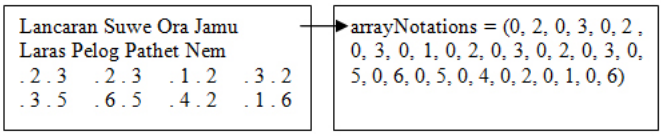

Fig. 11. Recording *balungan* notations into array data, and converting the dot notations into 0.

Time interval setting is the next phase after declaration of array containing *balungan* notations, The *balungan* notations are set based on *gatra* which contains 4 beats or notations. The tempo of the play usually is defined by an interval time, which is more less 1 second in playing the notation sequences. The application uses frame rate at 25 *fps*.

The automatic play feature is controlled by 3 variables, which are *tempo, beats,* and *totalNotations*. Variable *tempo* controls the tempo of the play. The default value of variable *tempo* is 25. *Tempo* is a dynamic variable which allow user to adjust its value and tempo of the play. Variable *beats* control time of the action in playing the notation. The value of variable *beats* is set at 0, and added incrementally, and when its value is greater than or equal to the value of *tempo*, variable *beats* is set to 0. Variable *totalNotations* controls the notation sequences detection. The value of variable *totalNotations* is set to 0, and added incrementally when the value of *beats* is greater than or equal to *tempo*, and when *totalNotations* is greater than or equal to the length of *arrayNotation*, it set to 0.

Below is the pseudocode for automatic play feature based on notation recognition, with the value of variable *tempo* is set to 25.

```
var arrayNotation:Array = (balungan notations)
var tempo:int = 25;
var beats:int = 0;
var totalNotation:int = 0;

Start
while totalNotations ≤ arrayNotation.length
    beats += 1;
    if (beats ≥ tempo)
      beats = 0;
      play sound = arrayNotation[totalNotations]
      play animation = arrayNotation[totalNotations]
      totalNotations += 1
    end if
end
Stop
```

IV. Implementation and Evaluation

The system is developed using Adobe Flash CS6 with ActionScript 3.0 as the programming language. The output is a mobile application which runs in *Android* platform. The dataset of *balungan notations* containing collection of *gending laras slendro* and *laras pelog* are embedded to the application. Features in the application allow user to choose and play a melodic abstraction instrument, to display notations, and to get a demonstration of technique of the play of the instrument based on the chosen *gending*.

The evaluation of the application is conducted using *user acceptance test*, where 3 *gamelan* music experts are involved to evaluate the application based on accuracy and clarity. All of the experts have practitioners background as the owner and the leader of gamelan music studio with decades of experience. The accuracy represents the ability of the application in playing the instrument with sound and animation which are fit to the *balungan* notations including the various tempo of the play. The clarity represents the ability of the application in visualizing the animation including display design which can be easy to understand and learn. The value range of 1-5 is used to measure the accuracy and clarity, where value of 5 indicates predicate of very accurate and very clear. The values given by experts are accumulated to define the mean value in percentage format.

The accuracy is evaluated based on features of single instrument and orchestra. There are three evaluation components for accuracy evaluation, which are reading notations accurately, playing in various tempo, and synchronizing sound and animation. There are 7 evaluation components for clarity evaluation, which are design, visualization, animation, sound, navigation, learning, interactivity. The result shows that the accuracy for orchestra feature reaches to 71.1%, and for a single instrument feature reaches to 84.4%. The result of clarity evaluation is 78.1%. Table I, II, and III shows the values given by experts for accuracy and clarity evaluation.

TABLE I. ACCURACY EVALUATION FOR SINGLE INSTRUMENT

Evaluation Components	Experts		
	I	*II*	*III*
Reading notations accurately	5	5	5
Playing in various tempos accurately	4	3	4
Syncronizing sound and animation accurately	4	4	4
	13	12	13

TABLE II. ACCURACY EVALUATION FOR ORCHESTRA

Evaluation Components	Experts		
	I	*II*	*III*
Reading notations accurately	4	3	4
Playing in various tempos accurately	3	3	4
Syncronizing sound and animation accurately	4	3	4
	11	9	12

TABLE III. CLARITY EVALUATION

Evaluation Components	Experts		
	I	*II*	*III*
Design	4	5	4
Visualization	5	4	4
Animation	4	4	5
Sound	3	3	4
Navigation	3	4	3
Learning	4	3	4
Interactivity	4	3	5
	27	26	29

V. CONCLUSION AND FUTURE WORKS

Virtual players of melodic abstraction instruments for *gamelan* music orchestra is designed to read gamelan songs notations and play the songs automatically. This method allows the application playing all the inputted *balungan* notation with output in term of audio, visual, and animation, and supports the play of the instruments in various tempos, which makes this application is able to accommodate the various skill levels of users.

In this research, the database of gamelan song notations is embedded in the systems. The database can be added at any number, but this makes the application being limited in playing *gamelan* songs. For the futures works, the research can be conducted by adding features of optical music recognition which allows the application to capture and interpret *gamelan* sheet music, and then play it automatically.

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